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Occurrence and Abundance of Larval Atlantic Menhaden, *Brevoortia tyrannus*, at Two North Carolina Inlets with Notes on Associated Species

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ABSTRACT

A comparison was made of relative indexes of abundance for Atlantic menhaden larvae entering two North Carolina inlets. Larvae entered the inlets from November through April 1966–67 and 1967–68, and were most abundant in March during both survey periods. Collections over 24 hours showed that larvae are more abundant at night than in the day and are more abundant in the slower tidal currents. As the larvae drift back and forth on the ebbing and flooding currents and feed on plankton, their condition factors (weight/length^3) increase. The abundance of 23 other species of fish collected with the menhaden is also discussed.

INTRODUCTION

Atlantic menhaden, *Brevoortia tyrannus*, spawn off the North Carolina coast in the winter and early spring. In December 1966 biologists of the National Marine Fisheries Service found a spawning site in Onslow Bay (Reintjes, 1969). In the bights where spawning occurs prevailing northeasterly winds cause elliptical, counterclockwise currents (Gray and Cerame-Vivas, 1963; Stefánsson and Atkinson, 1967). After hatching menhaden larvae probably are carried by these currents from the spawning sites to inlets.

The purpose of this study was to determine relative indexes of abundance of Atlantic menhaden larvae that moved through two adjacent North Carolina inlets and what factors influence abundance. We hope to assess the usefulness of larval abundance indexes as measures of spawning success and year-class strength. In the future we plan to determine which of the estuarine nursery areas supports the most young menhaden and what factors affect their well-being.

METHODS

From January to March 1966 we tested three types of nets for catching larval menhaden: a beam trawl, 1-m and 0.5-m conical nets, and channel nets. The fixed and portable channel nets[2] designed for catching larvae were the most successful gear. Each net had a 3-m^2 opening and a current meter attached at the mouth. The wings of the net were constructed of 3-mm square nylon webbing and for the cod end we used 0.5 mm opening nylon mesh. We attached the fixed net to a sliding frame which allowed us to sample at any depth between the surface and bottom. The cod end of the net was closed with a draw string to prevent it from fishing during retrieval. The portable net could only be fished at the surface and was held to a bridge or platform by ropes.

During our regular sampling seasons we used the fixed net at the laboratory bridge of the National Marine Fisheries Service inside of Beaufort Inlet and the portable net at the Highway #24 bridge inside of Bogue Inlet near Swansboro, North Carolina (Figure 1). We sampled both places in the 1966–67 and 1967–68 seasons but only did limited sampling at Swansboro in 1966–67. Except for this, sampling was the same for the years and locations involved. We compared abundance between years and locations by larval indexes (L. I. = number of larvae per 100-m^3 water). All menhaden larvae and associated species were measured to the nearest mm total length.

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[2] Lewis, R. M., W. F. Hettler, Jr., E. P. H. Wilkens, and G. N. Johnson. A channel net for catching larval fishes. Center for Estuarine and Menhaden Research, Beaufort, North Carolina, Typewritten Report, 2 pp.

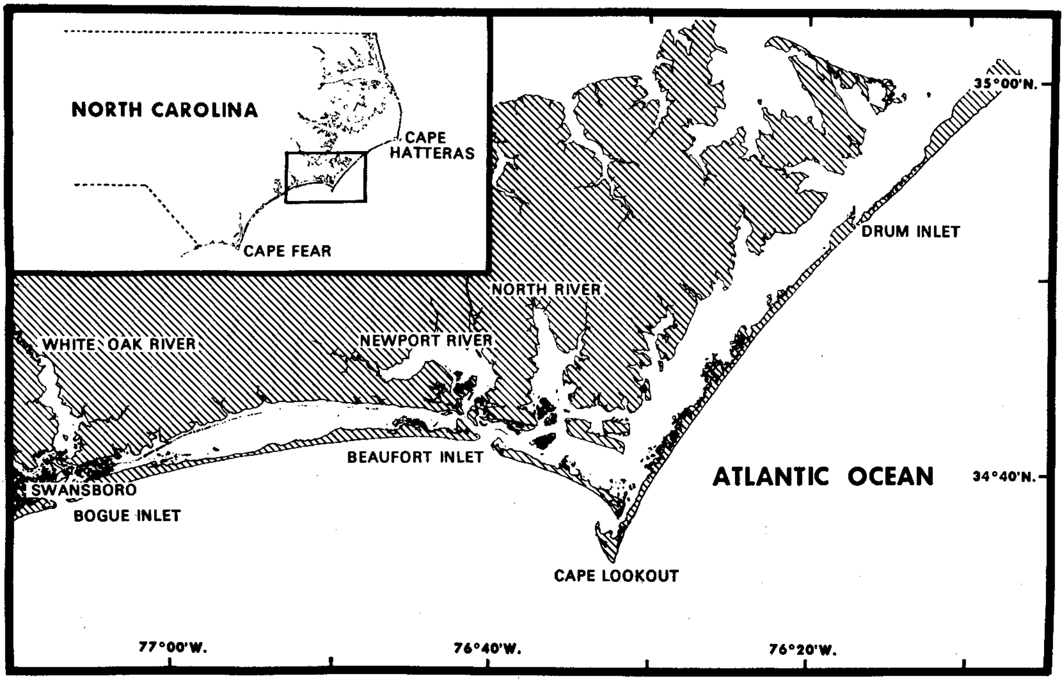

FIGURE 1.—A map of the study area. Highway #24 crosses the White Oak River east of Swansboro, North Carolina. Onslow Bay comprises the body of water along the North Carolina coast below Cape Lookout.

RESULTS AND DISCUSSION

After menhaden larvae move through an inlet on flood tide and into the lower estuary (the area just inside the inlet), the tidal currents sweep them back and forth in an area rich in plankton. Our field and laboratory observations showed that hakes, *Urophycis* spp.; spot, *Leiostomus xanthurus*; and pinfish, *Lagodon rhomboides* are abundant in the lower estuary when menhaden larvae enter it but we do not know the extent of their predation on menhaden. Williams, Murdoch and Thomas (1968) determined that the standing crop of zooplankton near the inlets in late winter and early spring is high. Thus menhaden larvae enter at a good time to benefit from this food supply.

Atlantic menhaden larvae entered Beaufort Inlet from November through April. Changes in larval abundance inside Beaufort Inlet during the winter and spring of 1966–67 suggested that the number of spawning fish off North Carolina was greatest from January to early March. Although we collected a few larvae in late November, the main influx was in the last half of March (Figure 2). The first larvae of this season were collected on November 9 and the last on April 28. From the number of larvae entering the inlet during 1967–68 it appeared that spawning probably was greatest in January and February but less than the previous year. In this season the first and last dates that we collected larvae were November 7 and April 24. We computed a peak larval index of 81.0 for 1966–67 as compared with 3.5 for 1967–68. A comparison of the areas under the curves for the two years (Figure 2) reveals that larvae were 13 times as abundant in 1966–67 as in 1967–68.

The relative abundance curves of menhaden larvae for Bogue and Beaufort Inlets were similar in 1967–68 (Figure 3). A group of larvae with a particular modal length would appear at Bogue Inlet a few days after a similar group had appeared at Beaufort. This indicates that the larvae entering Bogue and Beaufort Inlets probably originated from the same spawning site in Onslow Bay. Also,

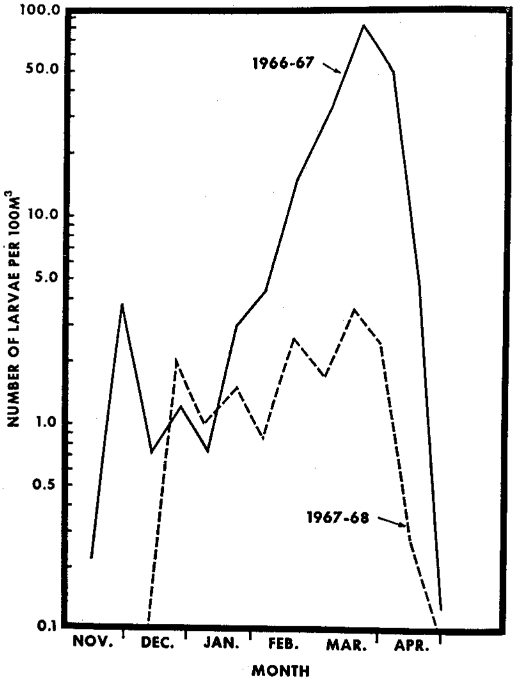

FIGURE 2.—Mean semimonthly Atlantic menhaden larval indices for 1966–67 and 1967–68 at Beaufort Laboratory bridge.

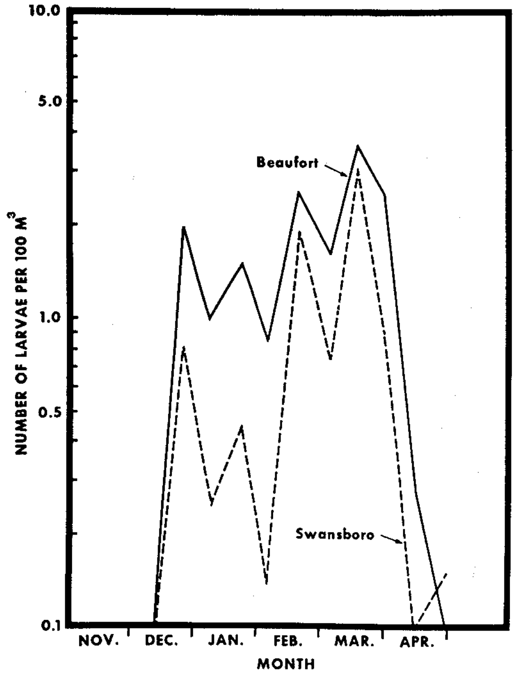

FIGURE 3.—Mean semimonthly Atlantic menhaden larval indices at Beaufort Laboratory bridge and Swansboro bridge during 1967–68.

the first seasonal appearance of larvae of other species generally was separated by only a few days at the two inlets. The abundance of larval menhaden at Bogue was about one-half that at Beaufort.

The abundance and movement of larvae at the sampling stations were affected by currents and tidal stages. To determine the distribution of larvae in the daytime at Beaufort, we used the following sampling procedure during the 1967–68 survey period. Four random surface and bottom sets were scheduled each day, but sometimes weather, tidal conditions and other events prevented us from making four sets. Due to the advance of about an hour per day of the corresponding stage of tide, we sampled different tidal stages on succeeding days. Mean larval indexes from surface and bottom sets were listed by tidal periods; each flood and ebb tide was divided into three, 2-hr stages (early, middle, and late) for surface and bottom sets (Table 1). When catches of larvae from flood and ebb tide periods were combined, higher larval indexes were obtained in the surface than in the bottom sets. When flood and ebb tide periods were separated, a comparison between surface and bottom sets for flood tide showed that more larvae were collected at the bottom than the surface. The reverse was true for ebb tide. Even though these trends exist, no significant difference occurred among the larval indexes for the net position or the tidal stage. The lowest and highest indexes in bottom sets during successive stages of flood tide suggested a patchy distribution of menhaden larvae. The mean larval index was 1.05 on mid-flood, and 5.43 on late-flood.

Other factors that affect the number of larvae caught in a set are temperature and wind conditions. When the water temperature was below 10 C during December, January and February the relative abundance of larvae decreased. During brisk winds few larvae were caught; the wind seemed to disperse the larvae or drive them away from the surface.

TABLE 1.—*Relative abundance of Atlantic menhaden larvae by tidal stage at two positions in the water column at the Beaufort Laboratory bridge during 1967–1968*

	Flood tide	Larval index (mean)	Number of observations	Standard deviation	Ebb tide	Larval index (mean)	Number of observations	Standard deviations	Total
Surface	Early	1.18	9	1.69	Early	2.82	24	5.01	
	Middle	1.38	12	1.56	Middle	2.64	28	4.07	
	Late	2.92	20	3.93	Late	3.11	12	7.74	
Totals		5.48				8.57			14.05
Bottom	Early	1.08	7	1.24	Early	1.15	19	1.75	
	Middle	1.05	11	1.28	Middle	2.41	19	5.92	
	Late	5.43	12	7.76	Late	2.28	12	2.87	
Totals		7.56				5.84			13.40

In March 1968 when we expected the most larvae, we sampled for 24 hr at the Beaufort Station to determine how tidal changes and diel cycle affected larval abundance. We fished our standard channel nets at the surface and bottom (depth at mean low tide 6.7 m) simultaneously for 30 min to measure the variation. The nets were always in the water except when we removed the samples from them. Larval indexes and velocity of current in meters per second on a logarithmic scale are plotted against hours to show the change of these factors with time (Figure 4). The catches in both surface and bottom sets between 0800 and 1830 hr were generally low. During the morning flood tide more larvae were caught in the bottom sets than in the surface sets. During the afternoon ebb tide more larvae were caught in the surface sets than in the bottom sets. At sunset, 1811 hr, the tide began flooding and for the next hour indexes of larval abundance increased at about the same rate in both the surface and bottom sets. But as the velocity of the current during flood tide increased at the surface (0.58 m/sec) and decreased near the bottom (0.23 m/sec), more larvae were caught in the bottom sets. The number of larvae collected from the bottom sets reached a peak during mid flood but a peak did not occur until late flood in the surface sets. During mid-ebb there was a marked difference between the number of larvae in the surface and bottom sets; more larvae were found in the bottom collections. At dawn the larvae showed no depth preference.

Larvae moved in a cyclic pattern related to both diel and tidal conditions. During the daytime larvae were found in about equal numbers near the surface and bottom depths. Scattering of larvae in the lower estuary probably occurred in the day during periods of slow current. At night larvae were most abundant near the bottom during mid-ebb and mid-flood tidal stages. The seeking of slower currents on the bottom at night may prevent them from being swept into unfavorable areas and help them to hold their position in an estuary until they are large

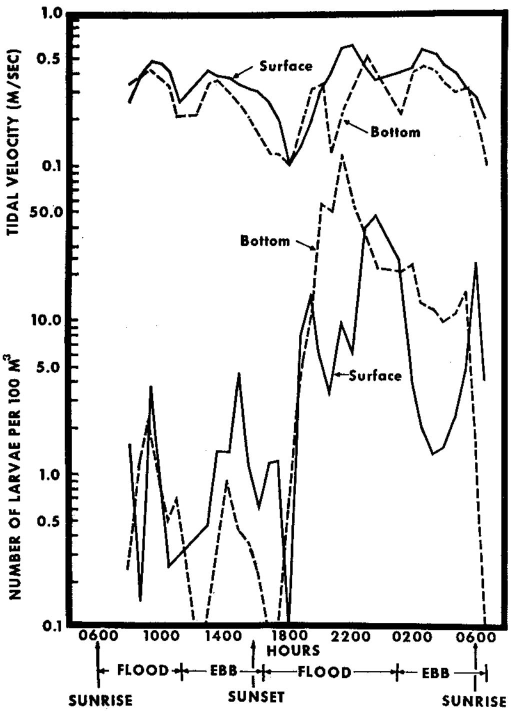

FIGURE 4.—Larval indices for Atlantic menhaden and velocity of current for a 24-hour period at Beaufort Laboratory bridge on March 19–20, 1968.

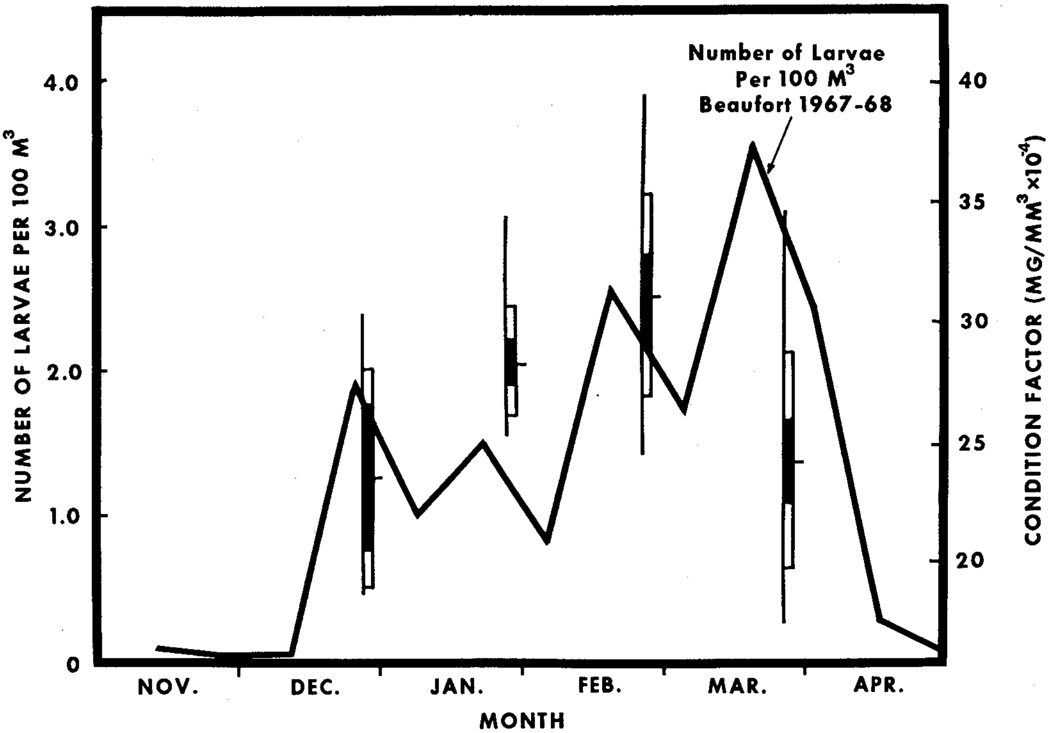

FIGURE 5.—Relation between larval index and condition factor for Atlantic menhaden larvae collected at Beaufort Laboratory bridge during 1967–68. Symbols: vertical line, range; horizontal line, mean; open rectangle, 1 standard deviation ± mean; closed rectangle, 1 standard error ± mean.

enough to move upstream to nursery areas. On the night of our study moonrise was at about 0030 hr, but due to the heavy cloud cover there was little illumination.

Relative abundance indexes were compared with condition factors from our larval collections at the Beaufort Station in 1967–68 to determine if the relation between these two factors could help us interpret the pattern of movement of larvae within the lower estuary. The condition factor (C.F. = 10,000 W/L^3, where W = weight in mg, L = length in mm; the ratio was multiplied by 10,000 to remove the decimal point) was determined for each specimen, and the mean of a collection was calculated. Specimens were dried on a paper towel to remove surface moisture and then weighed to the nearest tenth of a mg. The distribution of sample means of the condition factors is plotted in Figure 5 along with the larval index curve.

The means of the condition factors change with time. We grouped the samples collected within a month and then compared succeeding months from December to March. All comparisons were significant. The means of the condition factors are generally low in December, increase in January, reach a maximum in February, then decrease to a minimum in March. The steady increase from December through February was probably due to: 1) growth of larvae already in the estuary without recruitment of new small larvae or 2) addition of larvae with higher condition factors to the estuary or 3) differential growth of the larvae already in the estuary. The steady condition decline in March probably resulted from smaller larvae entering the lower estuary in greater numbers at this time, while the larger larvae had moved upstream. March was a month when the water temperature increased and food was abundant.

Menhaden larvae are slender when they first enter the lower estuary. As the larvae drift back and forth with the ebbing and flooding currents they feed on plankton, and their condition factors change as their weight increases faster than their length. As a result larvae that have been in the lower estuary for a long time have a higher condition factor than those that have just entered.

The following immature fishes were collected in association with larval menhaden at our Beaufort Station in daylight samples from November 1967 through April 1968. The first seven species discussed were the most abundant.

Spot, *Leiostomus xanthurus,* was the most abundant species even including menhaden. They were first taken during the latter part of November and were present for the remainder of the sampling season. Most of the spot were caught in February and their numbers declined sharply in late March and April.

The catch of the pinfish, *Lagodon rhomboides,* was similar to that of spot, except a sharp drop occurred during late January. The drop was probably related to water temperature which went below 4.0 C during the same period. Lewis (1965) demonstrated a 50% mortality of menhaden larvae when subjected to water of 4.0 C for 2 days or less, and we believe this temperature was also lethal to pinfish larvae.

Striped anchovy, *Anchoa hepsetus,* while not numerous, was present in the collections from November to mid-January. They were absent from mid-January to mid-April except for one larva caught on February 26. These larvae were 15 mm and longer. In late April larvae reappeared in the collections and were less than 10 mm total length.

Bay anchovy, *A. mitchilli,* adults and larvae were present in the samples from November until March 10.

Atlantic croaker, *Micropogon undulatus,* larvae occurred in the collections from November through April.

Young striped mullet, *Mugil cephalus,* ranging from 20–33 mm occurred in the samples from November to March. The number per set diminished markedly during March and mullet were absent from the samples in April.

Speckled worm eels, *Myrophis punctatus,* were collected as leptocephali from November through mid-April. A few pigmented and unpigmented elvers were caught but not identified.

Differences in catches on ebb and flood tide were noted only for anchovies. Over 80% of the *A. hepsetus* larvae were collected on flood tide. Most were caught in late April and were very small (6–8 mm). In contrast, most of the larger *A. mitchilli* larvae were caught on ebb tide (91%). The influx of small *A. hepsetus* in late April probably marked the beginning of their spawning period (Mansueti and Hardy, 1967), whereas the larger *A. mitchilli* larvae were probably washed from the upper estuary by the ebbing current.

Other immature fishes caught were: ladyfish, *Elops saurus*; silver anchovy, *Engraulis eurystole*; mummichog, *Fundulus heteroclitus*; hakes, *Urophycis* spp.; northern pipefish, *Syngnathus fuscus*; silver jenny, *Eucinostomus gula;* pigfish, *Orthopristis chrysopterus*; several species of gobies, Gobiidae; searobins, *Prionotus* spp.; southern stargazer, *Astroscopus y-graecum*; striped cusk-eel, *Rissola marginata*; butterfish, *Poronotus triacanthus*; Atlantic silverside, *Menidia menidia;* several genera of flounder, Bothidae; and filefishes, Balistidae, in part.

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